Official Copy

EFFECT OF WHEAT PLANTING DATE ON SOIL WATER EXTRACTION, GROWTH, AND YIELD[1]

Jack T. Musick and Steven R. Winter[2]

Abstract

Planting date and timely establishment are important factors in optimum adaptation of winter wheat to specific climatic environments. Optimal planting dates in the Southern High Plains are considered to be within a 3-week period of late September and early October. Previous studies have mostly addressed the yield reduction effects from late planting while little emphasis has been given to early planting except for grazing management. The need for additional information of planting date effects on soil water depletion, growth, and yield were addressed by field tests of early, normal, and late planting of irrigated and dryland wheat at Bushland, Texas. Compared with normal planting, early planting reduced grain yield in association with excessive early season growth, tillering, soil water depletion, and reduced dry matter partitioning to grain. Late planting greatly reduced early season growth, tillering, and soil water depletion. However, the enhanced reserve of soil water from reduced early season depletion by late planting was not efficiently used for reproductive growth because of reduced rooting depth. Advancing planting date for dryland treatments from early October to late August reduced grain yields from 47.4 bu/A for normal planting to 14.3 bu/A in 1990 and from 43.3 to 21.0 bu/A in 1991. Late planting (4 to 5 weeks delay) reduced dryland yields by 18.5 bu/A in 1990 and by 11.5 bu/A in 1991. Based on these tests and previous studies, non-optimum planting dates reduce grain yield primarily in the range of 3 to 8% per week.

Introduction

Planting dates are selected to optimize wheat yield potential for specific climatic environments. This paper discusses planting date effects in the Southern High Plains where normal planting is late September to early October. The Southern High Plains is a major region for production of both dryland and irrigated winter wheat. Planting dates are somewhat variable due to the need for seed zone soil moisture provided by variable precipitation.

---

[1]Contribution from USDA Agricultural Research Service and Texas Agricultural Experiment Station, Texas A&M University.

[2]Agricultural Engineer, USDA-ARS, (806)356-5728 and (806)356-5750 FAX; and Professor of Agronomy, TAES-TAMU, (806)354-5803 and (806)358-9718 FAX, respectively, P.O. Drawer 10, Bushland, TX 79012.

p. 144 - 157

Cumulative planting date probabilities are presented in Figure 1 for 37 years of planting dryland wheat without grazing in the Southern High Plains at Bushland, Texas (O. R. Jones, unpublished). Planting dates ranged from September 17 to November 2 with the 50% occurrence on September 27. In 80% of the years, winter wheat was planting by October 8, which is near the end of the normal planting period. Dryland wheat is frequently planted earlier than optimum to take advantage of favorable seed zone moisture and minimize the risk of seed zone drying.

In about one year in five, dry surface soil conditions delayed planting past the normal date and wheat was "dusted in". This usually occurred during a 3-week period after about October 10. Germination of "dusted in" wheat has usually occurred in time for adequate vernalization for reproductive development. In 15 years of winter wheat irrigation tests by the senior author, planting date for grain production without grazing averaged October 4, one week later than the average date for dryland wheat. Irrigated wheat managed for fall grazing by cattle is planted earlier as will be discussed later. Fall irrigation as preplant or emergence normally provides successful establishment and adequate fall growth when planted about one week later than dryland. Irrigation removes the requirement for precipitation to provide seed zone soil moisture.

In the Southern High Plains, early planted irrigated wheat (frequently as early as mid to late August) is commonly managed for fall and winter grazing by cattle. The cattle are removed as spring growth begins and wheat is further managed for grain production. Fall dry matter production from late August planting with adequate irrigation normally will produce about 4,000 lb/A of above-ground dry matter by the time of winter dormancy in early to mid-December. A mid-September planting date produces about 2,000 lb/A above-ground dry matter.

Both very early and very late planting can cause problems associated with grain yield reduction. Early planting can produce excessive fall growth, tiller numbers, and dry matter accumulation during a development stage when the excessive growth contributes very little or is detrimental to grain yield. Early planting also increases soil water depletion and seasonal water use. Under irrigated conditions, early planting managed for grazing by cattle increases irrigation requirement by about 20 to 30%. Fall growth that can reach about one foot height from early planting with adequate fall irrigation and high nitrogen fertility can lodge under snow cover. Tall lodged tillers and main culms can fail to regain an upright growth position and abortion of primary growth has reduced yields by up to 50%.

Early planted wheat is more likely to be affected by diseases such as leaf rust, viruses, and root and crown rot. Also, early planting advances early spring growth which reduces cold conditioning and advances the above ground position of the developing head. This increases susceptability to freeze damage. George (1982) indicated about 20°F as a critical temperature for 50% tiller loss when developing heads are 2 to 4 inches above the soil surface. The senior author measured similar losses by a mid-September planted wheat in one year when temperature fell to 10°F while developing heads were about 2 inches above the soil surface. October planted wheat with heads slightly below the soil surface largely escaped loss of primary tillers.

Late-planted winter wheat encounters cold temperatures and winter dormancy with very limited tillering, dry matter accumulation, and a limited root system. Tiller growth delayed by late planting and renewed by warming temperatures in late winter limits the extent of tiller and potential head density before tiller initiation ceases with floral initiation (Porter, 1985). Doubling of planting rates for a delayed planting test with adequate and deficit irrigation by the senior author did not adequately compensate for reduced tillering. Reduced dry matter production and head density were associated with significant yield reduction by late planting.

Very little data are available in the literature for yield reduction associated with early planting. Non-optimum planting date effects addressed in the literature primarily address late planting. Fischer (1981) summarized results from studies of fall-planted wheat on yield reduction per week of delayed planting past the optimum for production latitudes having a range of climatic environments. For two locations in India, the yield reductions were 10% per week at 18°N and 7% per week at 28°N latitude. For two location in Australia, the reductions were 6% per week at 31°S and 4% per week at 35°S latitude; and for one location in Turkey, the reduction was 5% per week at 40°N latitude.

Other literature indicate delayed planting at Pullman, Washington, (47°N) and at Bushland, Texas, (35°N) reduced grain yield by 6% per week (Thill et al., 1978; Musick and Dusek, 1980). For spring wheat grown at Prosser, Washington, delayed planting from early March to mid-April reduced yield by 4% per week (Nelson and Roberts, 1963). Delayed planting of spring wheat at Sidney, Montana, reduced yield by 7% per week and at Logan, Utah, by 7.7% per week (Sharratt et al., 1980).

In a line-gradient sprinkler irrigation study by Sharratt et al. (1980), an interaction yield effect was determined between planting date of spring wheat and water deficit. Under severe water deficits and low grain yield, planting date effects were small but increased significantly as water deficits were reduced and yield levels increased. Yield reduction from delayed planting, mostly in the 4 to 8% per week range, becomes a more significant yield factor in higher production environments.

Objectives and Procedures

Our objective was to evaluate early, normal, and late planting date effects for winter wheat related to soil water depletion, growth, and yield in irrigated and dryland tests at Bushland, Texas. Both the irrigated and dryland tests were designed to evaluate three planting dates designated as early, normal, and late. Planting dates for the irrigated test were September 15, October 12, and November 7. For the dryland tests, they were August 25, October 1, and November 3, 1989 (1990 season) and August 23, October 7, and November 12, 1990 (1991 season). Surface irrigation was applied to level plots to establish a wet soil profile at planting. Semi-dwarf cultivar 'TAM 101' was used in the irrigated test and 'TAM 107' in the dryland tests. Planting rates were 45 lb/A for the dryland tests and 90 lb/A for the irrigated test.

We discuss growth and development effects during Growth State 1 (GS1), emergence to floral initiation (double ridge stage of head differentiation); GS2, floral initiation to anthesis (flowering); and GS3, anthesis to physiological maturity. These major growth and development stages are further described for wheat by Musick and Porter (1990). Detailed procedures were reported for the irrigated test by Musick and Dusek (1980) and for dryland tests by Winter and Musick (1993).

The test site is centrally located in the major wheat production region of the Southern High Plains. Annual precipitation at Bushland averages 18.6 inches and winter wheat growing season precipitation averages 10.0 inches or about one-third of the seasonal water use requirement for high irrigated yield (Musick and Porter, 1990). The soil, Pullman clay loam, has plant-available water storage capacity to 6 ft of 9.7 inches. The depth of soil water depletion by winter wheat on this soil has ranged from 4 to 8 ft. When deep rooting occurs, root length density below about 5 ft appears to be limited by a calcic (soft caliche) horizon having calcium carbonate concentration by weight of about 45% in the first several inches and about 30% to the 12 ft sampling depth for soil water contents in the dryland tests. The soil is described by Unger and Pringle, (1981).

Results and Discussion

Soil Water Depletion

Data presented in Figure 2 illustrate a desirable seasonal distribution of soil water depletion for a high yielding (56 bu/A) dryland treatment with an initially wet profile and a normal planting date (October 2). This soil water depletion pattern, after beginning the season with a fully wet profile by irrigation, involves limited net depletion during GS1 (partially maintained in this example by late fall and early winter precipitation) and major depletion of available storage during the more critical stages of GS2 and GS3. These two stages determine the yield components of grain number and weight. Depletion depth in this test extended to about 5 ft during GS1 and increased to a maximum depth of about 7 ft during GS2.

The maximum depth of profile soil water depletion of the two-year dryland test for all three planting dates is presented in Figure 3. Data are plotted for end of fall growth (beginning of winter dormancy), the beginning of spring growth, and at anthesis. Gravimetric soil water content data were not taken after physiological maturity because of very wet soil conditions from precipitation in one season and very dry soil that prevented tube penetration in the other season. However, by anthesis, both early and normal planting dates resulted in significant depletion to the same depth, 8 ft, while depletion by late planting was limited to only 4 ft. Significant depletion was determined by analysis of variance of soil water content data with depth compared with fallow plots that began the season with similar profile water contents from preseason irrigation. This procedure prevented confounding of depletion data with profile drainage.

Net soil water depletion are presented in Table 1 for the three dryland planting date treatments during GS1 and GS2. In both years, early planting resulted in excessive depletion during GS1 which substantially reduced remaining available soil water storage and depletion during the more critical GS2. Late planting greatly reduced net soil water depletion during GS1. However, reduced depletion during GS1 did not significantly increase depletion during GS2 due to reduced rooting. The late planting treatment reduced soil water depletion with depth by anthesis in both the 1990 and 1991 test (Figure 4).

Plant Growth and Grain Yield - Irrigated Test

Fall planting date and temperature (heat units) have a major influence during GS1 on tillering, leaf area, and dry matter production. Effects of the three planting dates on tiller, stem, and head density from late fall to physiological maturity in a 1978 test are presented in Figure 5. The data are presented as number per square meter because of conventional usage. Note that both early and normal planting resulted in excessive tiller density during GS1 and abortion during GS2. Abortion of excessive tillers limits excessive head density and associated small head size which can reduce dry matter partitioning to grain.

Early planting of irrigated wheat on September 15 resulted in a late fall tiller density of 3,200/m^2, much higher than the final head density of 1,000/m^2. Dry matter at this time in late fall was near 2,000 lb/A. For late August planted wheat in grazing management tests, fall dry matter production has averaged about 4,000 lb/A under conditions of adequate irrigation and high nitrogen fertility. Under these conditions, late fall green leaf area has been measured as high as 10. When not harvested by grazing, the older green leaf area mostly dies overwinter and green leaf area does not exceed 6 during spring growth. The high basal leaf area associated with early planting has been observed to partially decompose during spring growth and probably contributes very little to grain yield. Excessive fall growth can occur for early-planted dryland wheat also and is discussed later for the dryland test.

The September 15 early planting date for the irrigated test developed wheat streak mosaic virus disease that was avoided by normal and late planting. Because of the disease effect, anthesis became the last date for dry matter sampling for early-planted plots and physiological maturity dry matter and grain yield were not determined (Figure 6). Normal planting with adequate irrigation produced grain yield of 84.7 bu/A compared with 63.5 bu/A by late planting. For a dryland control treatment included in the test, normal planting produced yields of 11.0 bu/A compared with 5.7 bu/A for the late planting.

Plant Growth and Grain Yield - Dryland Tests

Early planting greatly increased fall vegetative growth and net soil water depletion during GS1, Table 2. Increased soil water depletion by early planting and excessive fall vegetative growth increased water deficits and reduced vegetative growth during GS2. The early planting shift in dry matter production and soil water depletion to GS1 resulted in a reduction in dry biomass at maturity. This effect reduced both grain yield and harvest index and was less pronounced for the 1991 test when excessive late-fall vegetative growth was removed by mowing to simulate grazing compared with 1990 when early planted wheat was not fall mowed.

The effect of excessive vegetative growth during GS1, illustrated by early planting treatment effects in Table 2, has been observed in irrigated tests as a factor in limiting harvest index. Early planting, which increases both plant height and tiller and head density, reduces head size and seed per head. This results in a comparatively small head on a tall stem which reduces dry matter partitioning to grain. Although late planting increases harvest index, probably associated with a shortening of plant height and reduction in head density, the associated factors of reduced dry matter production, head density, and seed numbers reduce grain yield as shown for the dryland test in Table 2. Also, late planting does not effectively utilize available soil water storage in the lower profile associated with reduced rooting depth.

Concluding Discussion

Winter wheat in the climatic environment of the Southern High Plains requires about five months in GS1 (emergence to floral initiation). Early planting can increase this period to six months and late planting to four months or less. This contrasts with fall planted spring wheat in warmer temperature environments which has only about 5 weeks in GS1, thus limiting soil water depletion prior to reproductive growth. A common problem for dryland winter wheat in the Southern High Plains environment is excessive depletion of stored soil water during GS1 which substantially reduces remaining profile storage and increases water stress severity during reproductive growth. Optimum planting date is important to prevent excessive depletion and fall growth while being sufficiently early to allow time for moderate fall growth, tillering, and secondary root development. Late emerged wheat that tillers only in late winter prior to floral initiation has been observed to limit yield by limiting tillers, head density, and dry matter. Increasing planting rates by a factor of two have not compensated for late planting effects on grain yield reduction which appears to be associated primarily with reduced dry matter accumulation. The effects of non-optimum planting dates on grain yield reduction in these tests were in the low end of the range reported in the literature of 4 to 8% per week.

Precipitation predominantly occurs in the Southern High Plains during late spring to early fall with late fall to early spring being predominantly dry (Continental climate). Dryland winter wheat relies to a considerable extent on soil water storage at planting in addition to seasonal precipitation for high yield (Johnson and Davis, 1980). A wheat yield analysis for dryland production by Musick et al. (in press) emphasizes the importance of normal planting and emergence, high soil water storage at planting, deep rooting, and above normal seasonal precipitation for high grain yield.

Literature Cited

Fischer, R. A. 1981. Developments in wheat agronomy. pp. 249-269. In L. T. Evans and W. J. Peacok (eds.) Wheat Science -- Today and Tomorrow. Cambridge Univ. Press, New York.

George, D. W. 1982. The growing point of fall-sown wheat: A useful measure of physiological development. Crop Sci. 22:235-239.

Johnson, W. C., and R. G. Davis. 1980. Yield-water relationships of summer fallowed wheat. A precision study in the Texas Panhandle. USDA-ARS ARR-S-5.

Musick, J. T., and D. A. Dusek. 1980. Planting date and water deficit effects on development and yield of irrigated winter wheat. Agron. J. 72:45-52.

Musick, J. T., and K. B. Porter. 1990. Wheat. pp. 597-638. In B. A. Stewart and D. R. Nielsen (eds.) Irrigation of Agricultural Crops. Agronomy Monograph 30. Am. Soc. Agron., Madison, WI.

Nelson, C. E., and S. Roberts. 1963. Spring wheat variety, population, and planting date experiment. Washington Agric. Expt. Stn. Cir. 419.

Porter, J. R. 1985. Approaches to modeling canopy development in wheat. pp. 69-81. In W. Day and R. K. Arkin (eds.) Wheat Growth and Modeling. NATO ASE Series A: Life Sciences Vol. 86. Plenum Press, New York.

Sharratt, B. S., R. J. Hangs, and J. K. Aase. 1980. Environmental factors associated with yield differences between seeding dates of spring wheat. Utah Agric. Expt. Stn. Res,. Rep. 92.

Thill, D. C., R. E. Witters, and R. I. Papendick. 1978. Interactions of early and late-planting winter wheat and their environment. Agron. J. 70:1041-1047.

Unger, P. W., and F. B. Pringle. 1981. Pullman soils: Distribution importance, variability, and management. Texas Agric. Expt. Stn. Bul. B-1372.

Winter, S. R., and J. T. Musick, 1993. Wheat planting date effects on soil water extraction and grain yield. Agron. J. 85:912-916.

Table 1. Net profile soil water depletion during GS1 and GS2 for dryland planting date treatments, 1990 and 1991.

Planting date	Net Soil Water Depletion, In.	
	GS1 planting to FI	GS2 FI to anthesis
1990		
Early August 25	5.12	1.57
Normal October 1	3.03	3.90
Late November 3	0.51	4.53
1991		
Early August 23	4.80	1.18
Normal October 7	2.60	4.41
Late November 7	0.35	3.54

Table 2. Grain yield, mature dry matter and harvest index for dryland planting date treatments, 1990 and 1991.

Planting date	Grain yield	Mature dry matter	Harvest index
	bu/A	lb/A	
1990			
Early August 25	14.3	4,730	0.16
Normal October 1	47.4	10,360	0.25
Late November 3	28.9	5,710	0.27
1991			
Early August 23*	21.0	3,440	0.32
Normal October 7	43.3	5,760	0.40
Late November 12	31.8	3,830	0.44

*Fall growth mowed before winter dormancy to simulate grazing cattle.

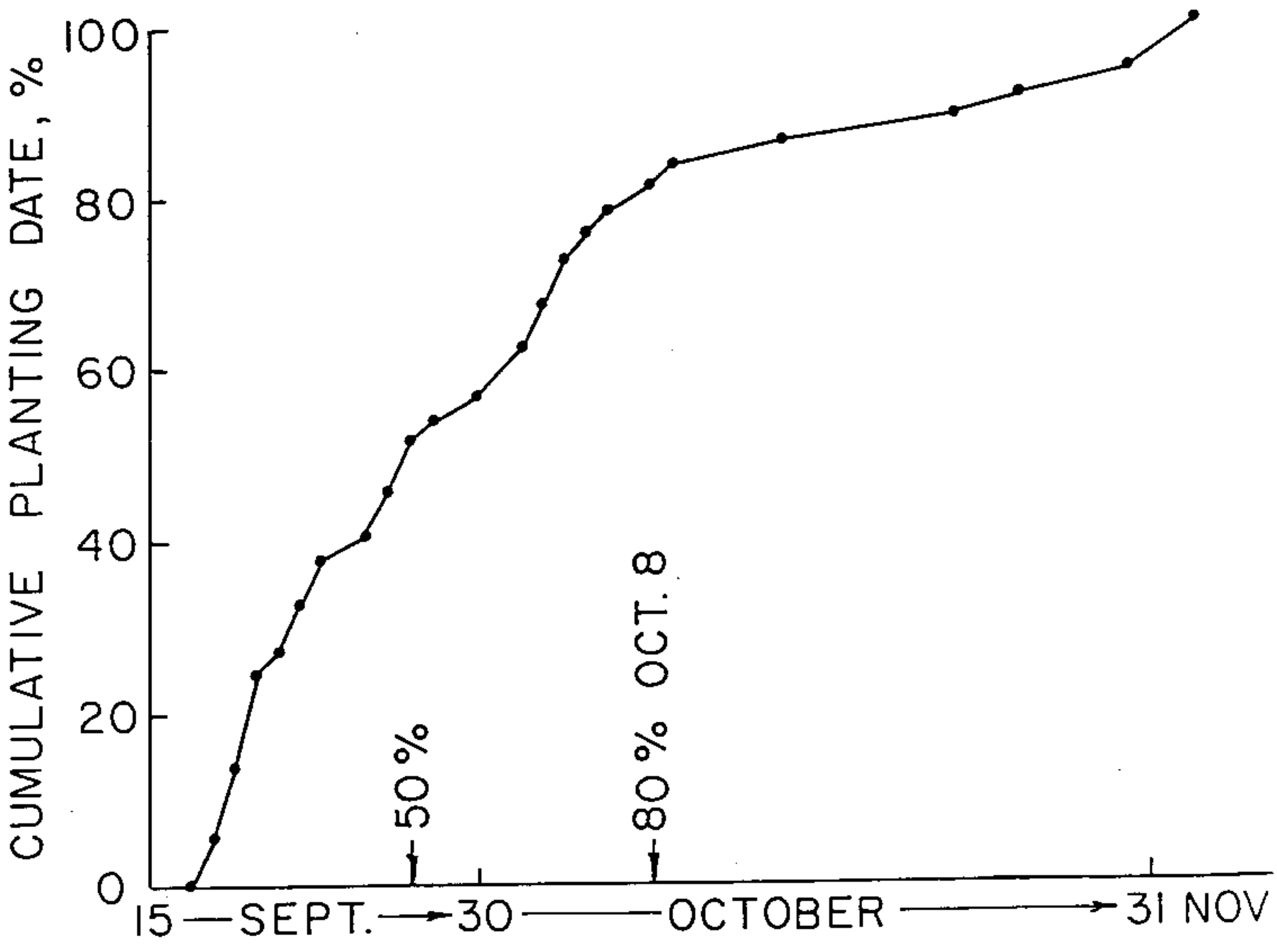


Figure 1. Planting date cumulative probabilities for 37 years of dryland wheat, Bushland, Texas (data from O. R. Jones).

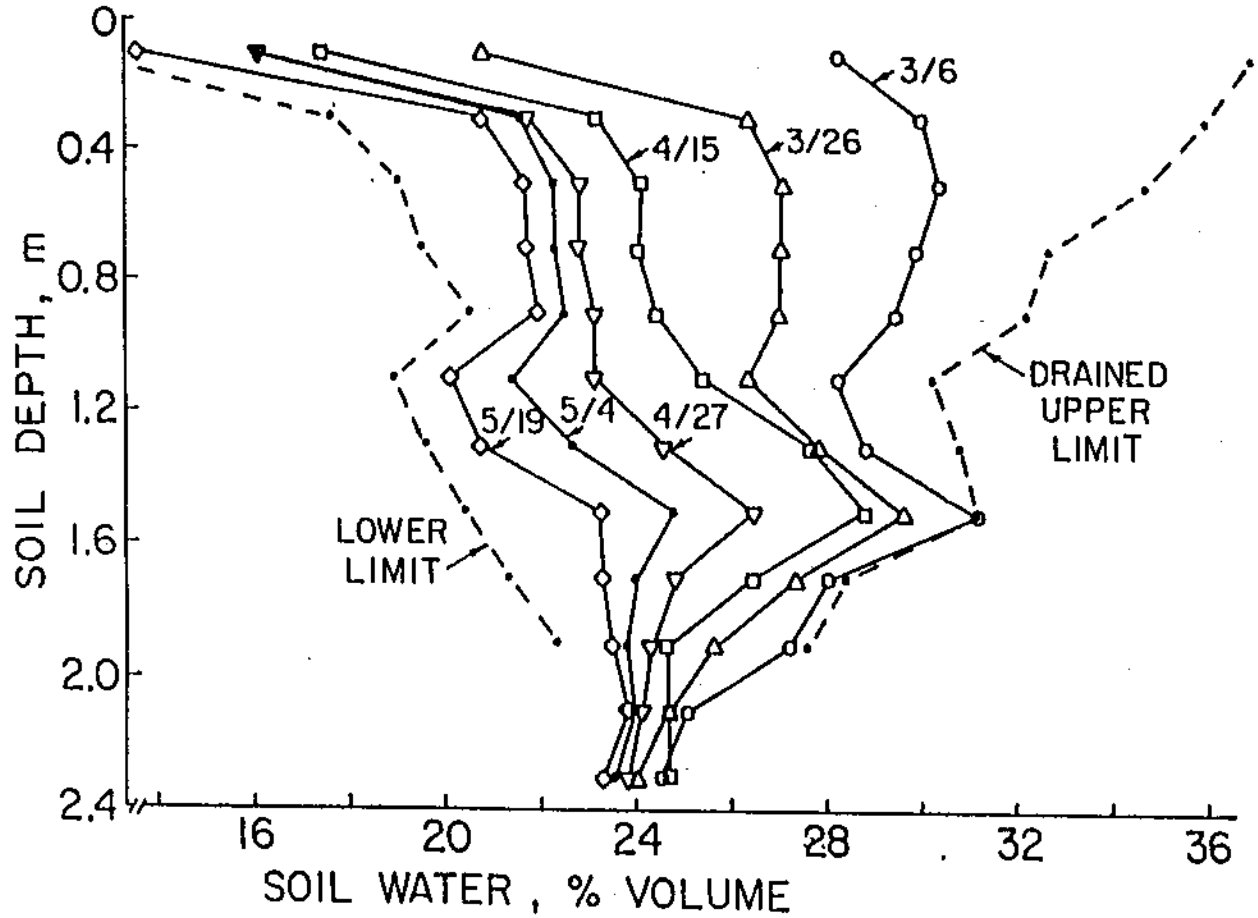


Figure 2. Illustrative profile soil water depletion by a normal winter wheat planting date (October 2) dryland treatment that was wet to the drained upper limit by irrigation prior to planting. Floral initiation occurred on March 6 and anthesis on April 27. Rainfall partially rewet the soil after the last sampling date shown on May 19 and physiological maturity on May 29, preventing further evaluation of depletion for late grain filling.

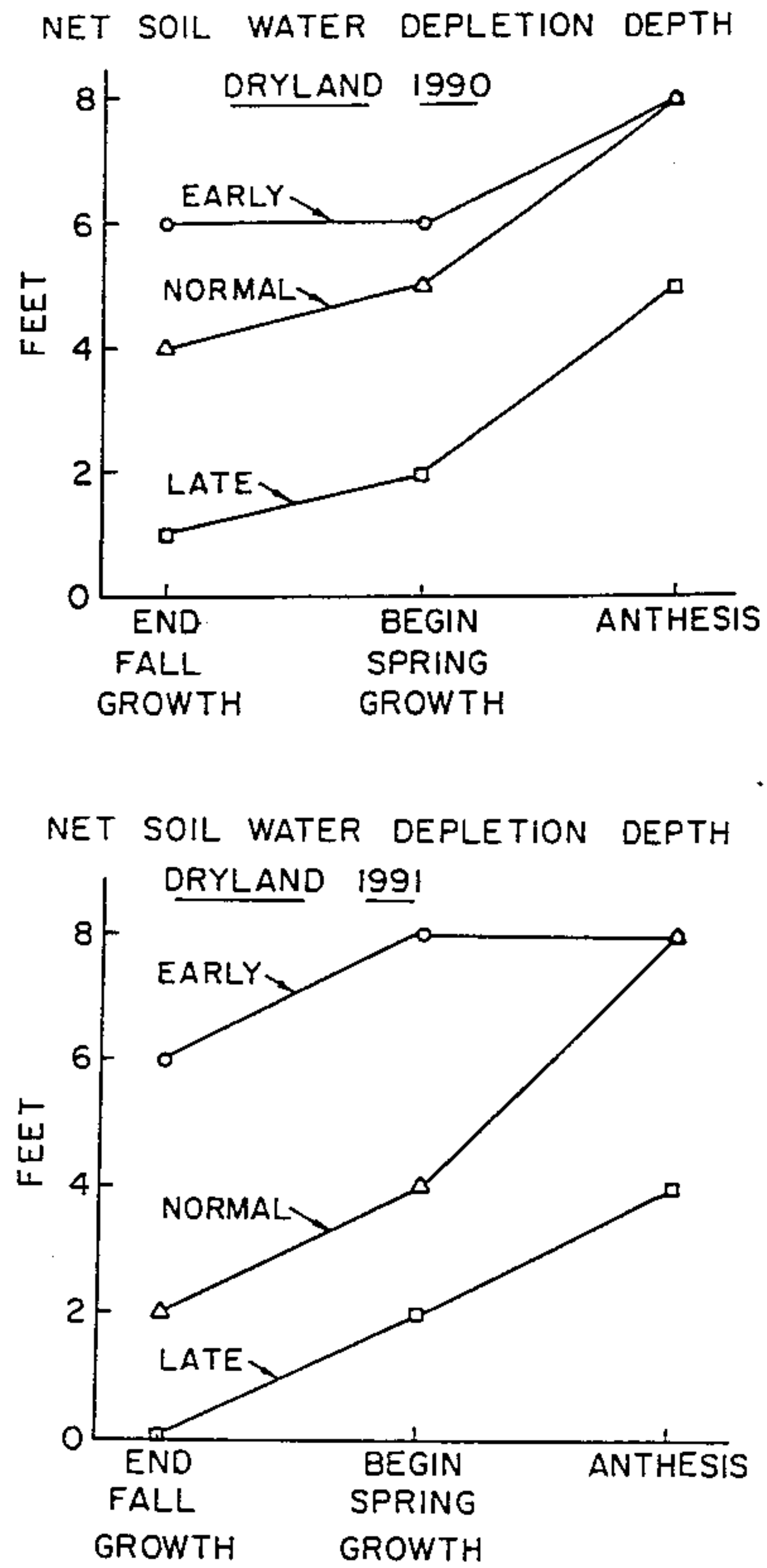


Figure 3. Net soil water depletion depth by dryland planting date treatments measured at the end of fall growth, beginning of spring growth, and anthesis, 1990 and 1991.

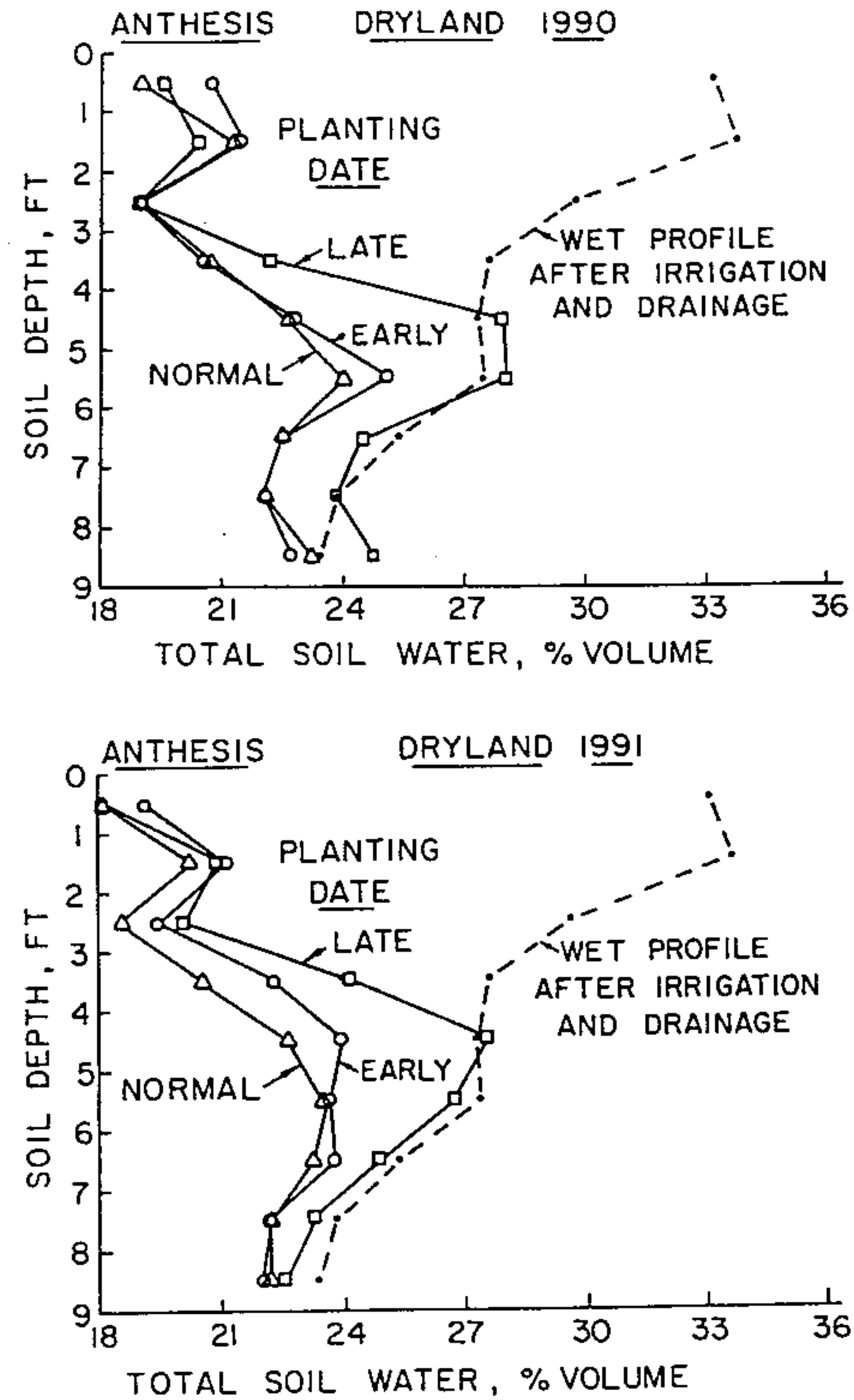


Figure 4. Dryland planting date soil water contents at anthesis that indicated treatment effects on depletion with depth, 1990 and 1991.

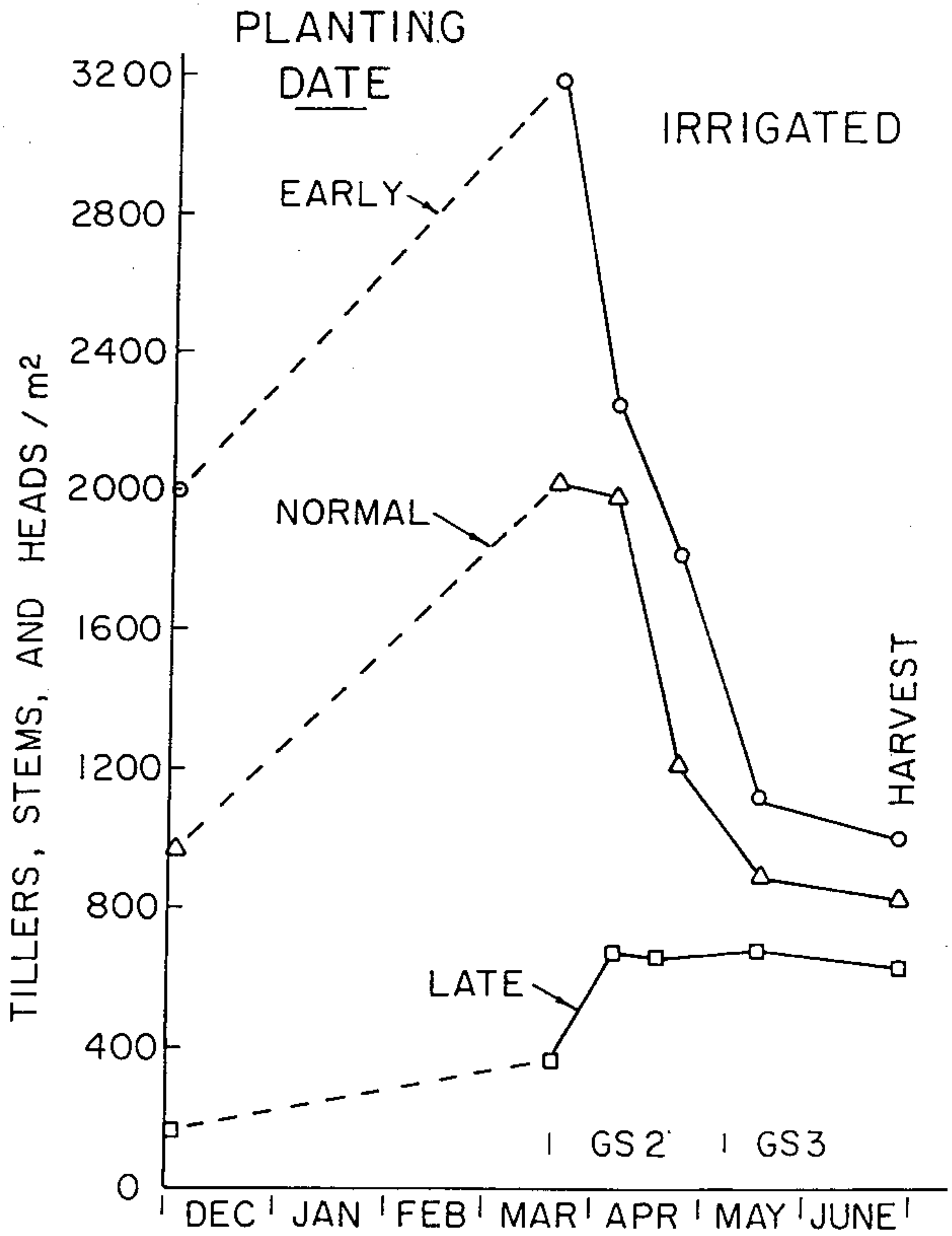


Figure 5. Irrigated planting date treatment effects on developing tillers, stems, and head density, 1978.

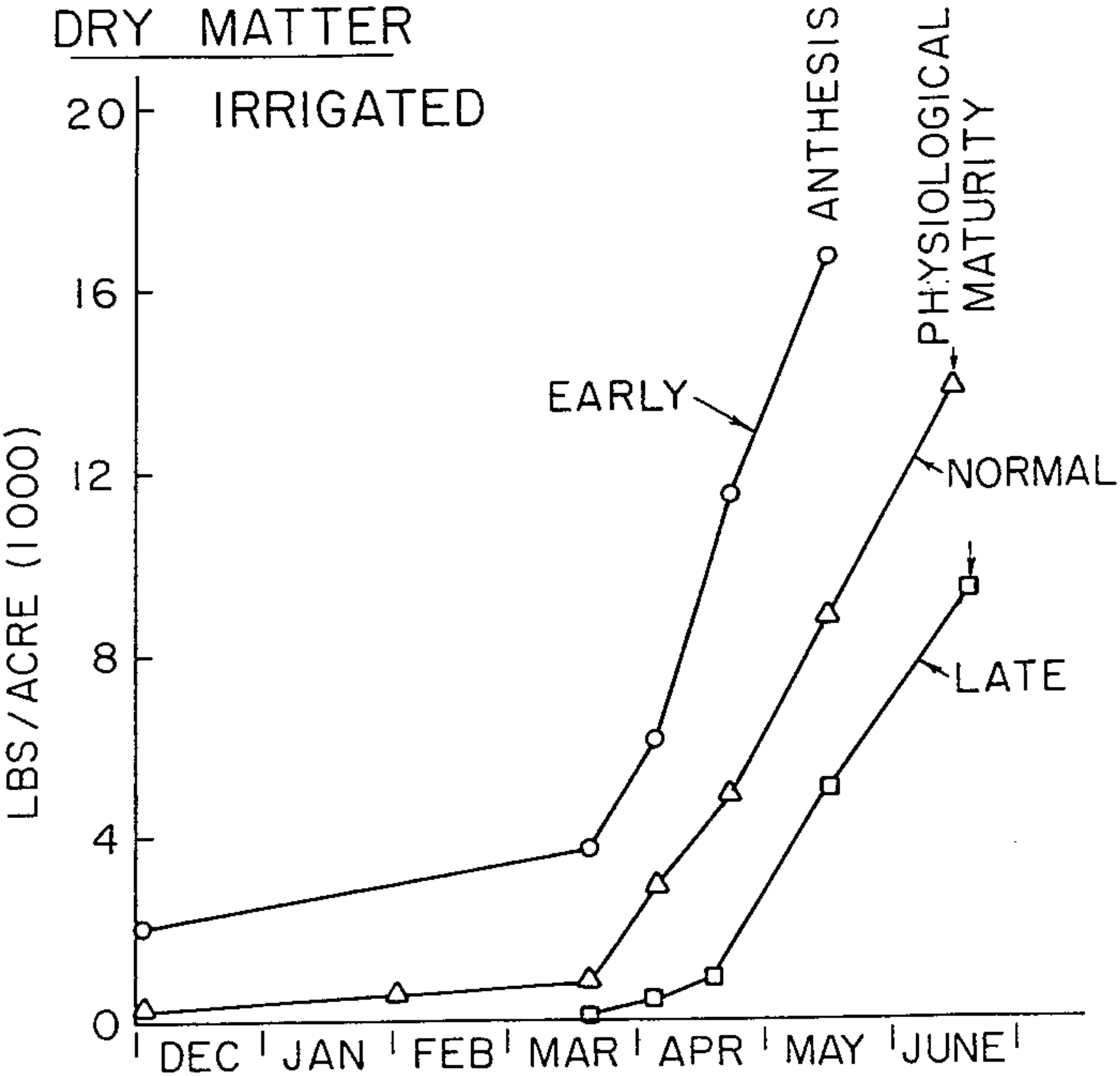
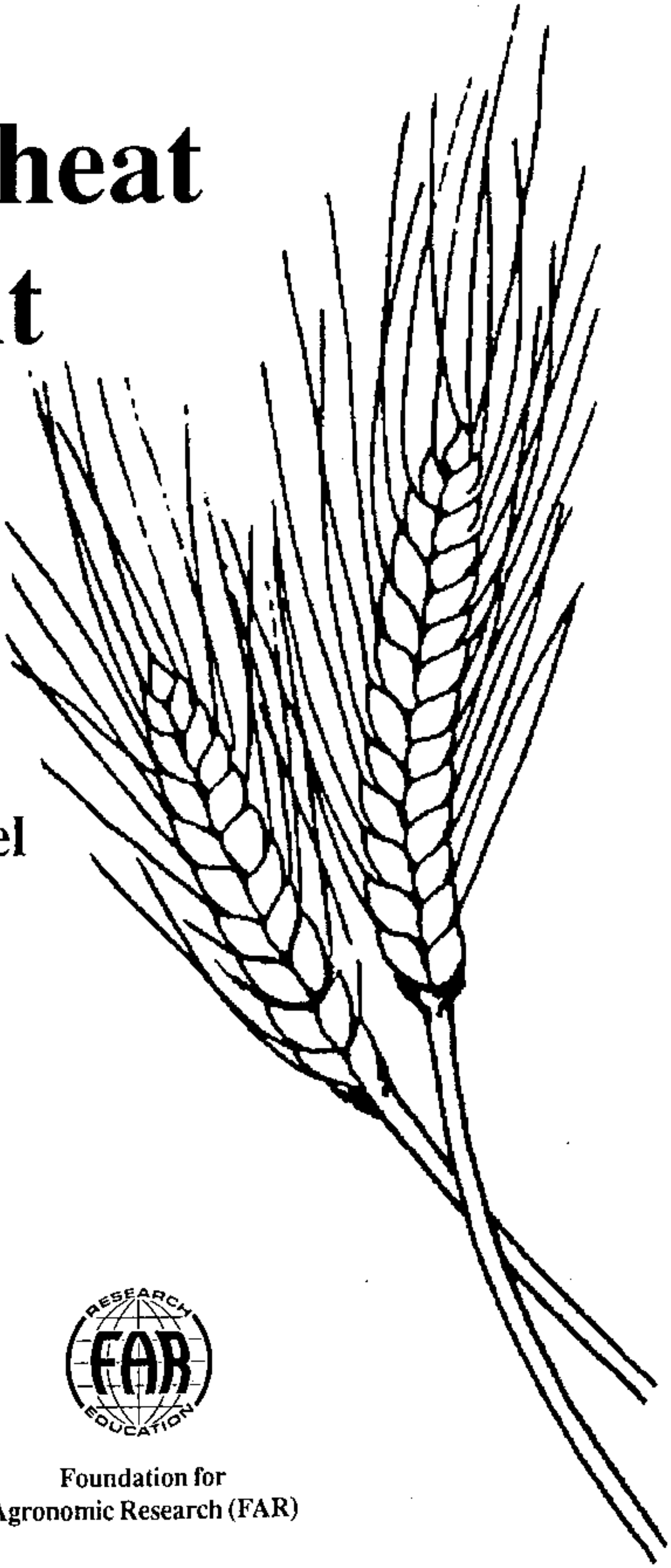


Figure 6. Irrigated planting date treatment effects on dry matter accumulation, 1978. Dry matter sampling of early planted treatment was terminated at anthesis because of developing wheat streak mosaic virus disease.

Proceedings

Intensive Wheat Management Conference



March 10-11, 1994

Stouffer Concourse Hotel

3801 Quebec Street
Denver, Colorado 80207
Phone: (303) 399-7500

Organized by:

Potash & Phosphate Institute (PPI)

Foundation for Agronomic Research (FAR)

Co-Sponsored by:

Farm Journal
Farmland Industries